Claims 1-24

In response to the applicants' previous arguments for patentability (in the Amendment and Response filed January 2, 2003), the Final Office Action provides an illogical paragraph starting on the bottom of page 3 and continuing onto the top of page 4. Applicants believe that Liu only discusses chevrons twice. Once in column 1 at lines 31-35 when it is said that parallel rubbing creates a chevron structure and anti-parallel rubbing creates a quasi-bookshelf structure. The second time is in column 4 at lines 35-37. The argument in the Final Office Action is understood to be the following: "Liu says in the background that typical SSFLC devices create chevron structures that result in high transmission losses. Liu creates a device wherein excellent contrast is provided, so his device must be free of chevrons." It is not understood how that "conclusion" logically results from Liu's disclosure. It is not necessarily the case that if A causes B, then the lack of B proves the lack of A. It is also not clear that "high transmission losses" and "excellent contrast" are the complement of each other.

As was argued previously, Liu never clearly discloses a chevron-free structure. The closest he comes is when he mentions a "quasi-bookshelf" structure. Liu does not define this term or use it in sufficient context to be able to tell exactly what he means. For assistance in understanding this term, we have attached a copy of relevant passages from a textbook on the subject, Ferroelectric and Antiferroelectric Liquid Crystals, by Sven T. Lagerwall (1999). As is demonstrated in the underlined passage carrying over from page 225 to page 226 and the underlined passage in the caption to Figure 98 on page 227, a quasi-bookshelf structure is known in the art to be a structure that has the chevrons "straightened-out" by the application of an electric field.

Each of the rejected claims, however, is directed to a device that is free of chevron structures without a need to otherwise apply an additional treatment to the optical device. The application of an electric field to "straighten-out" the chevrons is just the type of additional treatment that is not required by the claimed invention.

Claims 25 and 26

Claims 25 is patentable not only because of the limitation discussed in the immediately preceding paragraph, but also at least because of the surface stabilized limitation in Claim 25. The Final Office Action states on page 3 that Liu discloses "a non-surface-stabilized ferroelectric liquid crystal material to provide a chevron-free structure." (underlining added) It is not understood how this can be seen to anticipate the applicants' invention, which has a surface stabilized limitation. Liu's disclosure is directed to non-surface-stabilized structures, by his own admission (col. 2, lines 23-25, col. 8, line 24, and col. 9, line 25).

Claim 26 is patentable at least because of the limitations discussed above in conjunction with Claims 1-24.

Based upon the foregoing, Applicants believe that all pending claims are in condition for allowance and such disposition is respectfully requested. In the event that a telephone conversation would further prosecution and/or expedite allowance, the Examiner is invited to contact the undersigned.

Respectfully submitted,

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Ferroelectric and Antiferroelectric Liquid Crystals

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Cover picture:
Zigzag defects in a smectic C*.
Courtesy of Noel Clark and Tom Rieker.

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way between 1 and 2), which gives a contribution to the threshold for the process. Generally speaking, the bulk switching on either side of the chevron interface preceeds the switching in the interface. The latter contributes to the latching and thus to the bistability.

As seen from Fig. 96b, the switching process is unambiguous as regards the motion of ***n*** and ***P*** (sterically bound to ***n***): on the upper side of the chevron, ***P*** rotates counterclockwise, on the lower side it rotates clockwise when we switch from 1 to 2; everything turns around in the reverse switching direction. This explains why there are no twist and antitwist domains like the ones observed in twisted nematics prior to the time when chiral dopants were added in order to promote a certain twist sense.

So far we have described the switching concentrating on the chevron interface, completely disregarding what could happen at the two bounding (electrode) surfaces. In fact, if the anchoring condition on the surfaces is very strong, switching between up and down states of polarization will only take place at the chevron interface. At high voltage this will more or less simultaneously take place in the whole sample. At low voltage it will be possible to observe the appearance of down domains as "holes" created in an up background, or vice versa, in the shape of so-called boat domains (see Fig. 105) in the chevron interface (easily localized to this plane by optical microscopy). The walls between up and down domains have the configuration of strength one (or 2π) disclinations in the ***P*** field.

It should be pointed out that the uniqueness of director rotation during the switching process is not a feature related to the chevron per se, but only to the fact that the chevron creates a certain ***P***-tilt at the chevron interface. If the boundary conditions of the glass surfaces involved a similar ***P***-tilt, this will have the same effect.

A glance at Fig. 97 reveals another important consequence of the chevron structure. As ***P*** is not along ***E*** (applied field) there will always be a torque ***P***×***E*** tending to straighten up the chevron to an almost upright direction. Especially in antiferroelectric liquid crystals, which are used with very high *P* values, this torque is sufficiently strong for almost any applied field, for instance normal addressing pulses, to raise and keep the structure in a so-called quasi-bookshelf structure (QBS) under driving conditions. In ferroelectric liquid crystals, presently with considerably lower *P* values, the same effect was previously employed to ameliorate contrast and

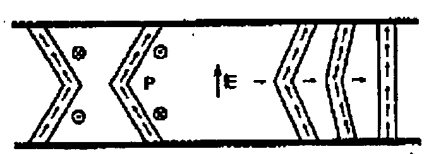

Figure 97. The fact that even after switching the polarization ***P*** is not entirely in the direction of the applied field will tend to raise the chevron structure into a more upright position, so decreasing the effective δ but breaking up the layers in a perpendicular direction. This gives a characteristic striped texture from the newly created, locked-in defect network.

threshold properties, by conditioning the chevron FLC to QBS FLC by the application of AC fields [169]. The effect on the switching threshold can be extracted from Fig. 96. When the chevron structure is straightened up, δ decreases and the two cones overlap more and more, leading to an increasing distance between 1 and 2, as well as further compression of the tilt angle θ in order to go between 1 and 2. The threshold thus increases, in agreement with the findings of the Philips (Eindhoven) group. On the other hand, this straightening up to QBS violates the conservation of smectic layer thickness d_C, which will lead to a breaking up of the layers in a direction perpendicular to the initial chevrons, thus causing a buckling out of the direction running perpendicular to the paper plane of Fig. 97.

8.4 Analog Grey Levels

As we just pointed out, in the chevron structure the polarization is no longer collinear with the external field. This can be used (for materials with a high value of P) to straighten up the chevron into a so-called quasi-bookshelf structure, combining some of the advantages from both types of structure. For instance, it can combine a high contrast with a continuous gray scale.

How to produce analog gray levels in an SSFLC display is perhaps not so evident, because the electrooptic effect which we have essentially dealt with so far offers two optical states, hence it is digital. Nevertheless, the shape of the hysteresis curve reveals that there must be small domains with a slightly varying threshold, in some analogy with the common ferromagnetic case. Normally, however, the flank of the curve is not sufficiently smeared out to be controlled and to accommodate more than a few levels. Curve I of Fig. 98 shows the transmission–voltage characteristics for a typical SSFLC cell with the layers in the chevron configuration [165]. The threshold voltage is fairly low, as well as the achievable transmission in the bright state, leading to a low brightness–contrast ratio. The position and sharpness of the threshold curve reflect the relatively large and constant chevron angle δ_0 in the sample. If a low frequency AC voltage of low amplitude (6–10 V) is applied, the smectic layers will be straightened up towards the vertical due to the $P-E$ coupling, so that the local polarization vector increases its component along the direction of the field. This field action, which requires a sufficiently high value of P, breaks the layer ordering in the plane of the sample and introduces new defect structures, which are seen invading the sample. The result is that the chevron angle δ is reduced, on average, and the threshold smeared out, as shown by curve II. Lower δ means a larger switching angle (and higher threshold), and thus higher transmission. Still higher transmission can be achieved by an additional treatment at a somewhat higher voltage (±25 V), giving threshold curve III, corresponding to a new distribution around a lower δ-value and a microdomain texture on an even finer scal .

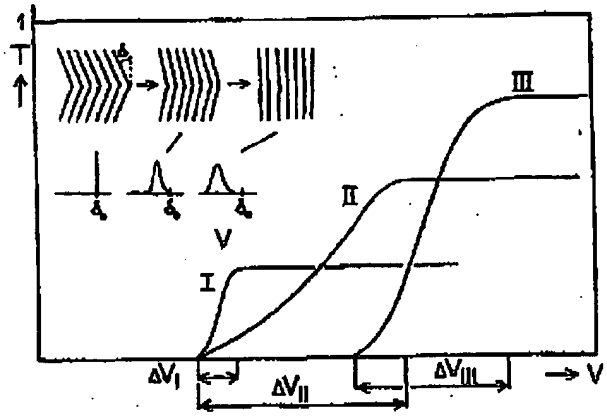

Figure 98. Amplitude-controlled gray scale in SSFLC. The chevron structure is transformed to a quasi-bookshelf (QBS) structure by external field treatment. In addition to giving gray shades, the QBS structure increases the brightness and the viewing angle. This method of producing gray levels was developed by the Philips (Eindhoven) group, who called it the "texture method".

The actual switching threshold is a complicated quantity, not fully understood (no successful calculation has been presented so far), and usually expressed as a voltage–time area threshold for the switching pulse. For a given pulse length it is, however, reasonable that the amplitude threshold increases according to Fig. 98 when the average value of δ decreases. There are at least two reasons for this, as illustrated by Fig. 96. First, it is seen that the distance between the two positions n_1 and n_2 in the chevron kink level (which acts as a third, internal surface), as well as the corresponding positions at the outer surfaces and in between, increase when δ decreases. It would therefore take a longer time to reach and pass the middle transitory state, after which the molecules would latch in their new position. In addition, it is seen that the local deformation of the cone i.e., a decrease of the tilt angle θ, which is necessary to actuate the transition from n_1 to n_2, increases when δ decreases. (A paradox feature of this deformation model is that it works as long as $\delta \neq 0$, whereas $\delta = 0$ gives no deformation at all – but also no chevron – at the chevron kink level.)

The smectic layer organization corresponding to curves II and III of Fig. 98 is generally characterized as a quasi-bookshelf (QBS) structure, denoting that the layers are essentially upright with only a small chevron angle. The QBS structure has a very large gray scale capacity. This might, however, possibly not be utilized to advantage in a passively driven display (as it can in the AFLC version). Its drawback in this respect is that the shape of the threshold curve is temperature-dependent, which leads to the requirement of a very well-controlled and constant temperature over the whole area of a large display. Furthermore, the QBS structure is a metastable state. Finally, the microdomain control of gray shades requires an additional sophistication in the electronic addressing: in order to achieve the same transmission level for a given applied amplitude, the inherent memory in the microdomains has to be deleted, which is done by a special blanking pulse. Using this pulse, the display is reset to the same starting condition before the writing pulse arrives. As a result of these features, it is not clear whether the microdomain method will be successfully applied